Analysis of daily rainfall characteristics on sub-seasonal to inter-annual time scales in NW South America using a HMM model

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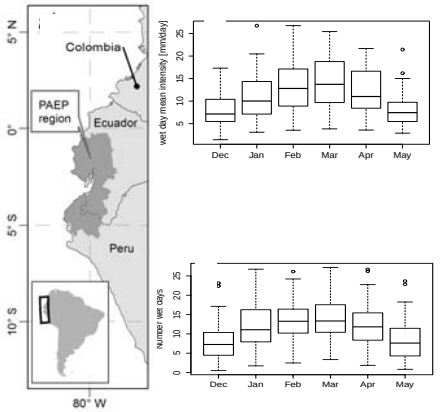
Abstract

A ~46 year record of daily Dec-May rainfall at a network of 68 stations located in the westernmost axis (0-6ºS) of South America, the Pacific-Andean basin in Ecuador and Peru (PAEP), is analyzed using a hidden Markov Model (HMM),

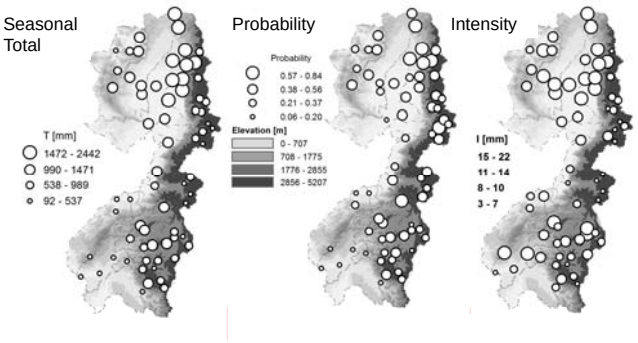
The diagnosed states are seen to play distinct roles in the course of the onset, mature and retreat phase of the rainy season. The estimated daily state-sequence is characterized by a systematic seasonal evolution, together with considerable variability on intra-seasonal and inter-annual time scales. One pair of states represents wet-versus-dry conditions at all stations, while as second pair represent north-south gradients. The first one could be associated with the annual moisture off-shore the PAEP region and the annual southward displacement of the Inter-tropical convergence zone and moisture conveyed from the Amazon region. Inter-annual variation are associated with the annual variations in the frequency of occurrence of wet and dry states and is well correlated with EL Niño 1.2 region.

PAEP region in NW South America

- ✓ Dec-May daily rainfall 1964-2010 (8372d)
- ✓ Nearly uni-modal distribution. Peak MAM
- ✓NS differences: Wet North/dry south
- ✓ No typical WE altitudinal gradient
- ✓ Strong topographic modulation



Daily rainfall characteristics



HMM model as diagnostic tool

Assumptions

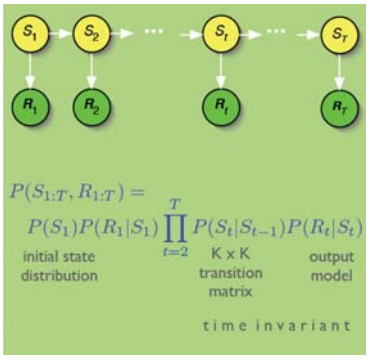
1. *Rt* at time t are independent of all other variables in the model up to time t, conditional on the weather state *St* at time *t*.

$$P(\mathbf{R}_t|S_{1:t}, \mathbf{R}_{1:t-1}) = P(\mathbf{R}_t|S_t)$$

2. Hidden state process, *S1:T*, is first-order Markov:

$$P(S_t|S_{1:t-1}) = P(S_t|S_{t-1})$$

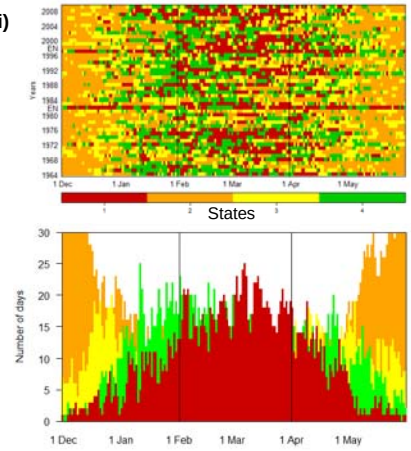
3. The HMM factorizes the joint probability distribution



Sub and Seasonal variability

States sequence (Viterbi)

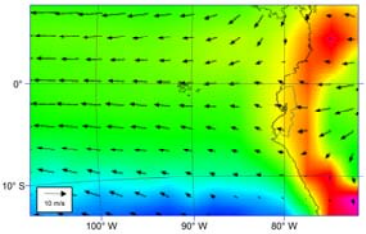
- ✓ S1: Wet (+) humid everywhere. Centred in FMA (peak), except EN years.
- ✓ S2: Dry (+) dry all stations . Opposite sign to S1
- ✓S3: Dry (-) Transition dry wet conditions (onset)
- ✓ S4: Wet (-) Transition wet dry conditions (retreat). Larger *P* and *I* north of 2.5ºS

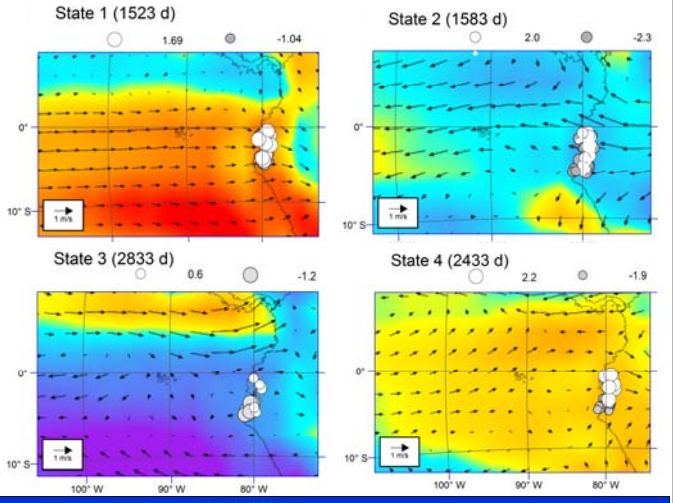


Atmospheric correlates

- ✓ Climatology: Blocking moisture over P AEP
- ✓ S1: oceanic moisture off -shore PAEP (south of 2ºN)
- ✓ S2: Easterlies and northward flow again ITCZ
- ✓ S3: Adynamic zone off-shore PAE and *qa* coolest maxima
- ✓ S4: South and eastward expansio of two centres of moisture.

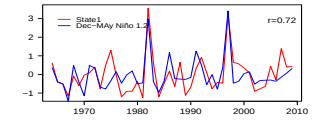
Specific humidity (*qa*)and horizontal winds 85 hPa

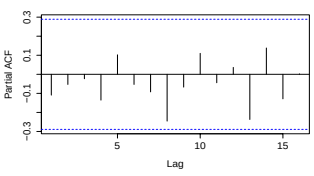




Interannual variability

- ✓ S1 synchronized with Dec-May EN 1.2, specially peak events.
- ✓ S2 correlation with EN 1.2 (=-0.65) but it does indicate opposite phase (i.e. LN)
- ✓ S4: 1-2 year periodic fluctuations. ITCZ and/or SMAs (expansion/contraction) modulated by EN.





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